above the surface on which it rests. But any abrupt change in the slope of the surface near the gauge, whether it be an embankment across a valley, a cliff, or a steep roof, or tower, allows the wind to set up eddies, or acquire an increased velocity, and so to reduce the amount of rain received in a horizontal gauge." These principles are clear enough, and they show the need for the adoption of a uniform height of gauge by all members of the rainfall organisation. At present it appears that not half the gauges in use are placed at exactly the standard height.

MESSRS. SWAN SONNENSCHEIN AND CO. have published a third and revised edition of "Land and Fresh-water Shells," by Mr. J. W. Williams, with a chapter on the distribution of the British land and fresh-water Mollusca, by Mr. J. W. Taylor and Mr. W. Denison Roebuck.

THE additions to the Zoological Society's Gardens during the past week include a Sooty Mangabey (*Cercocebus fuliginosus*) from West Africa, presented by Mr. G. Nicholson; a Rhesus Monkey (*Macacus rhesus*, ♀) from India, presented by Mr. J. McCarthy; a Short-toed Eagle (*Circaëtus gallicus*) from the Atlas Mountains, presented by Captain W. R. Taylor; a Passerine Parrot (*Psittacula passerina*) from South America, presented by Mr. W. C. Stronge; two Turtle Doves (*Turtur communis*), British, presented by Miss L. Cox; a Greek Tortoise (*Testudo graeca*) from South Europe, presented by Mr. Balfour Read; a Neumann's Baboon (*Cynocephalus neumanni*) from Central Africa, a Nisnas Monkey (*Cercopithecus pyrrhonotus*) from East Africa, a Striped Hyæna (*Hyaena striata*, var.) from North Africa, three Pale Fennec Foxes (*Canis pallidus*) from the Soudan; a Brazilian Caracara (*Polyborus brasiliensis*) from South America, a Black-headed Conure (*Conurus nanday*) from Paraguay, an Egyptian Monitor (*Varianus niloticus*) from North Africa, two Brazilian Tortoises (*Testudo tabulata*) from South America, two Sculptured Terrapins (*Clemmys insculpta*) from North America, three Muhlenberg's Terrapins (*Clemmys muhlenbergi*) from North America, a Pennsylvania Mud Terrapin (*Cinosternum pennsylvanicum*) from North America, three Laughing Kingfishers (*Dacelo gigantea*) from Australia, two White-capped Tanagers (*Stephanophorus leucocephalus*) from Argentina, three Striated Tanagers *Tanagra striata*) from Buenos Ayres, four Palm Tanagers (*Tanagra palmarium*) from South America, a King Snake (*Coronella getula*) from North America, two Ocellated Sand Skinks (*Chalcides ocellatus*) from North Africa, deposited; four Lesser Snow Geese (*Chen nivalis*) from North America, two Mute Swans (*Cygnus olor*), European, purchased; a Thar (*Hemitragus jemlaicus*), born in the Gardens.

## OUR ASTRONOMICAL COLUMN.

SPECTRUM OF NOVA PERSEI.—A communication from Prof. Pickering to the *Astronomische Nachrichten* (Bd. 156, No. 3735) gives particulars of the examination of recent photographs of the spectrum of the Nova taken at the Harvard College Observatory. The reductions show that, as has been the case in previous Novæ, the object has been gradually changing into a gaseous nebula. The resemblance to the nebula N.G.C. 3918 was so close on June 20 that no marked difference in the two spectra was noticeable. The main point of divergence is in the relative intensity of the chief nebular line at λ5007, which in N.G.C. 3918 is about eight times as bright as Hβ, while in the Nova these two lines are about equal in intensity.

The following lines are common to both bodies:—

| | |
|---|---|
| 3869 | 4688 |
| 3970, Hε | 4862, Hβ |
| 4102, Hδ | 4959 |
| 4341, Hγ | 5007 |

and with the above-mentioned exception of λ5007 are of similar intensity. Four bright lines between Hγ and Hβ appear faintly in the Nova, and are not present in the nebula, while one, at λ4364, is seen in the nebula, but not in the Nova, perhaps owing to the proximity of Hγ.

NEW DOUBLE STARS.—*Bulletin* No. 3, from the Lick Observatory, contains a list of 94 new double stars discovered by Mr. R. G. Aitken, with the 12-inch and 36-inch telescopes, the majority of the measures being obtained with the larger instrument. The series has been compared with Prof. Burnham's Catalogue to ensure the absence of duplicate records of previous discoveries. Classified according to distance of their components the 94 pairs show the following grouping:—

| | | |
|---|---|---|
| Under | 0″·25 | 3 |
| | 0·50 | 23 |
| | 1·00 | 47 |
| | 2·00 | 73 |
| Over | 5·00 | 1 |

SIX STARS WITH VARIABLE RADIAL VELOCITY.—Prof. W. W. Campbell gives particulars in *Bulletin* No. 4 of the Lick Observatory of six additional spectroscopic binaries, of which variable velocity in the line of sight has been determined from spectra obtained with the Mills spectrograph of the Lick Observatory. The details of the measures are given below:—

| Star. | Extreme velocities (kilometres). | |
|---|---|---|
| π Cephei | −37 | −5 |
| $o_1$31 Cygni | −12 | +3 |
| ξ Piscium | +25 | +35 |
| τ Persei | +10 | −4 |
| $\xi_1$ Ceti | −9 | +4 |
| ε Hydræ | +43 | +32 |

CAUSES OF THE VARIABILITY OF EARTHSHINE.—In the May number of the U.S. *Monthly Weather Review*, Mr. H. H. Kimball gives an interesting discussion of the probable causes of the earthshine observed on the moon's shadow side some few days previous to, and following new moon. With the idea that the amount of light reflected from the earth to the moon will vary considerably according to the condition of the earth's surface and atmosphere, a special projection chart of the earth has been prepared, showing the configuration of the continents, oceans, &c., and general atmospheric conditions (clouds, &c.), on a certain evening when the earthshine was specially prominent. If the bright portion is snow-covered, it will reflect more than a continent of forest and vegetation, and much more than a large extent of water.

A factor of considerable importance is the varying distance of the moon, and it is stated that 52 per cent. of the change in intensity of the earthshine is due to the eccentricity of the moon's orbit, and this is probably much greater than could be expected from any increase or diminution in the average cloudiness over the hemisphere of the earth reflecting light to the moon.

## SOLAR RADIATION.

SOLAR radiation is a subject which has more than scientific interest. It is the source of all the energy which maintains the economy of our globe. It lights and heats the other members of the planetary system. But, after accomplishing this, only an infinitesimal proportion of the total radiation has been used. The remainder, in so far as we know, is wasted by uninterrupted dissipation into space.

The subject can be regarded and studied from either the solar or the terrestrial point of view. In terrestrial physics everything may be said to depend on the energy which, in one form or another, is supplied by the sun's rays. It is the revenue of the world, and it is of fundamental importance for us to know at what rate it falls to be received.

Roughly speaking, the surface of the earth is occupied to the extent of one-fourth by land and three-fourths by sea. Therefore at least three-fourths of the surface which the earth presents to the sun is at the sea-level. Consequently the rate at which the sun's radiant heat arrives at the sea-level is the fact which it is of the greatest economical importance to ascertain.

In considering this problem we have to answer two questions: What is the best experimental method of determining the heating power of the sun's rays at any place? and What is the best locality for making the experiment? Let us take the last first. The energy which a radiation communicates to a surface is greatest when it strikes it perpendicularly. At every moment the sun is vertical over one spot or another of the earth's surface. Therefore our first step should be to choose a locality where the sun passes through the zenith at mid-day.

Before reaching the sea-level the sun's rays have to pass through the whole thickness of the atmosphere. It is a matter of every-day observation that the atmosphere varies in transparency. The second condition is therefore to put ourselves in the position of greatest advantage as regards atmospheric conditions. Clouds and similar visible obstructions are of course excluded. The air should be motionless, the sky should be clear and of a deep blue colour in the regions remote from the sun and should contain nothing that can be called haze, or that interferes with the definition of the sun or other heavenly bodies.

From inspection alone we can only approximately ascertain what are the most favourable meteorological conditions. For this reason it is necessary to multiply observations and never to miss fine weather. In the end we cannot fail to approach nearer and nearer to the exact determination of the maximum heating power of the sun on the earth's surface at or near the sea-level, in so far as the degree of perfection of our instrumental resources permits. This limitation imposes on us the duty to continue observations, not only until the best natural conditions have been found, but also so long as the instruments or experimental methods appear to be capable of improvement. If we suppose for one moment that we have arrived at the point where no further improvement is possible, then the result of our work is the determination of the rate at which unit area of the earth's surface at or near the sea-level receives heat from the vertical sun in unit time.

There is no question here of how much is lost on the way from the sun. All that is sought, and the most that is ascertained, is how much arrives. If we multiply this by the area included in the great circle of the earth we have the amount of radiant heat which we can count on as being supplied to the whole earth in unit of time. This is the constant which is of greatest importance in physical geography.

When we have ascertained the supply of radiant heat which reaches the earth's surface, we have to inquire what becomes of it. If the heat were to accumulate the world would become uninhabitable. It cannot be doubted that long ago the earth, in this respect, arrived at a condition of equilibrium which is maintained with very slight oscillations. The fundamental principle of this state of equilibrium is that the heat which the whole earth receives from the sun in the course of a year also leaves it in the course of a year, so that, taking one year with another, the sum of the heat remains the same.

When we study the details of the annual dissipation of heat we find that the atmosphere, and especially the aqueous vapour in it, performs a very important part. Although practically transparent to the heat-rays passing from the sun to the earth, it is very opaque to those leaving the earth to pass outwards. They are powerfully absorbed and the temperature of the atmosphere is thus raised considerably above that which it would have if it were as transparent to the leaving rays as it is to the entering ones. This has no effect in permanently detaining any of the year's supply, it still disappears in the year, but not before it has produced important climatic effects.

We see in this differential behaviour of the atmosphere towards the incoming and the outgoing rays an example of Kirchoff's law, in virtue of which a body absorbs by preference the rays which it itself emits. It is exceedingly unlikely that any portion of the rays coming directly from the sun proceed from highly heated water or water vapour; we should therefore not expect the water vapour in the atmosphere to absorb them to any appreciable extent. When, however, they strike the surface of the earth, whether it be land or sea, they are abundantly absorbed. The blue water of the ocean transmits the sun's visible rays to a considerable depth. In experiments made by the writer on board the *Challenger*, a white surface, about four inches square, was clearly visible at a depth of 25 fathoms. The total length of the path of the incident and reflected ray was 50 fathoms; therefore the sun's rays which strike the sea have a thickness of at least 100 metres to work on. When they strike the land, the direct effect is superficial, but the absorptive power of a surface of soil is very much greater than that of a surface of water, and it frequently attains a very high temperature. Even in the driest countries the soil is moist, and it may be that, ultimately, the surface of every particle of the soil is a water surface. Whether this be so or not, when a land surface cools, the heat of low refrangibility which it radiates proceeds to a very large extent from water, and it is accordingly abundantly absorbed by the water vapour in the lower layers of the atmosphere. In the absence of mechanical mixture by wind, these layers can lose it only by passing it on by radiation to higher layers which contain moisture, whence it ultimately escapes into space. This accumulating function of the atmosphere provides that while every portion of the earth's surface receives heat intermittently it loses it continuously.

As the heat of the atmosphere is due to contact with, or radiation from, the surface, it must be taken from the supply that reaches the surface of the earth. Further, wind and all mechanical atmospheric effects are due to differences of density, and these are produced, not only by the thermal expansion and accompanying rise of temperature of the air, but also, and without change of temperature, by the mixture with it of a lighter gas. Such a gas is the vapour of water, and the water which supplies it is at the level of the sea. Therefore the sun's heat which arrives at the surface of the earth at or near the sea-level has to maintain not only the temperature of the surface of the globe, it has also to maintain all the mechanical manifestations of the air and the ocean. This is the ground for asserting, as above, that the only constant which is of interest in terrestrial physics is the rate at which the vertical sun heats unit area of the earth's surface at the sea-level.

The instruments used for measuring the thermal effect of the sun's rays must fulfil certain conditions. The area of the sheaf or bundle of rays collected must be accurately known; and provision must be made for the exact measurement of the thermal effect produced by them in a given time. The thermal effect produced is measured by a mass of some substance and either by the change of temperature produced in it or by the change of its state of aggregation. Actinometers, such as those of Herschel, Pouillet, Violle, Crova, are instruments of the first kind. The ice calorimeter used by Exner and Röntgen and the steam calorimeter of the writer are instruments of the second kind. The thermal mass of the substance affected is conveniently expressed in terms of the thermally equivalent weight of water, which is called its water value. In the actinometer the change of temperature is either measured by a separate thermometer or the actinometer is itself a thermometer the calorimetric constants of which have been ascertained. In instruments of the second class no thermometer is required; the thermal effect is measured by the mass of water-substance which changes its state in a given time either from ice to water or from water to steam, both being at the same temperature. In the ice calorimeter the quantity of liquefaction is measured by the change of volume, as in Bunsen's calorimeter; in the steam calorimeter the generation of steam is measured by the weight or volume of the distilled water produced. The steam calorimeter was described recently in NATURE (vol. lxiii. p. 548), and it is unnecessary to repeat it here. It acted quite satisfactorily in the writer's hands in Egypt in May 1882, and it has since been giving good results in the hands of Mr. Michie Smith at the observatory of Kodaikanal in South India, at an elevation of about 7000 feet above the sea. Theoretically, the ice calorimeter is as good as the steam calorimeter, but in applying it to the measurement of the sun's radiant heat it has a practical defect. At the moment before exposure, the ice in the calorimeter is frozen to the inner surface of the metal plate, the outer surface of which receives the sun's rays. The first effect of exposure to the sun is that the ice is detached from the plate. The intervening water introduces perturbations which are not easily allowed for.

The fundamental principle of the actinometer is analogous to Newton's second law of motion; when a body is engaged in the exchange of heat between itself and any number of other bodies, each exchange takes place independently of the others. The rate of exchange in each case depends on the difference of temperature between the two bodies and takes place on the principle that equal fractions of heat are lost or gained in equal times. A body cooling in the air is always subject to at least two quite independent sources of loss of heat, namely, radiation between itself and the surrounding objects and conduction between itself and the contiguous air. In ordinary circumstances the rate of loss of heat by radiation is subject to but little variation, but that due to conduction is subject to continual variation owing to the varying rate at which the air actually in contact with the thermometer is renewed. It is not to be expected that a body subject to at least two independent sources of loss of heat will cool in the same way as it would if exposed to only one, any more than it is to be expected that a body acted on by two forces will move in the same way as if it were impelled by only one of them. The composition of rates of cooling is like that of velocities in the same straight line; the resultant rate is the net, or algebraic, sum of all the rates. When the actinometer is exposed to the sun, its temperature rises at first rapidly, and then more slowly until, if the experiment is sufficiently prolonged, it becomes stationary. The temperature is noted at equal intervals of time. The sun is screened off, either after the temperature has become stationary or beforehand, and the temperature is observed at equal intervals during cooling. Whenever the thermometer is at a higher temperature than its enclosure, it is cooling. Therefore when it is exposed to the sun's rays, and its temperature rises ever so little above that of the enclosure, cooling begins; and what is observed in the first operation is, not the rate of heating by the sun's rays, but that rate diminished by the rate at which the thermometer is cooling. Hence, when the two series of observations have been made and tabulated, the rate of rise of temperature when that of the thermometer is, say, 2°, 4° or 6° above that of the enclosure is found. Similarly, the rate of fall of temperature when the temperature of the thermometer is 2°, 4° or 6° above that of the enclosure during cooling is found. Three pairs of rates are thus obtained. The sums of all three pairs of rates should be alike, and each gives a value of the rate at which the temperature of the actinometer would rise when exposed to the sun if there were no cooling. The rule is the same whether the temperature is allowed to rise to the stationary point or not. A distinction is often made between the *static* method, when the experiment is continued until the stationary temperature is arrived at, and the *kinetic* method, when it is interrupted before that temperature is reached. This distinction rests on no substantial difference; at the same time it is convenient to retain the designations to distinguish the manipulative processes.

Were the protecting enclosures, such as the double spherical shell packed with melting ice, used by Violle, or the thick metal shell used by Crova, perfectly efficient, then it would not be necessary to make a separate cooling experiment in connection with every heating one. The necessity for it is due to the fact that, when the sun's rays are introduced, the temperature of the air in the enclosure no longer is, and it cannot be, at the temperature of the enclosing shell; nor can it remain motionless, as it is when at a constant temperature in the shade. These perturbations, which cannot be avoided, so long as there is air in the enclosure, make it impossible to apply a rate of cooling determined beforehand. It is necessary on each occasion to determine the actual integral rate of cooling during the particular experiment.

If the actinometer could be so arranged that the rate of cooling should not be affected by the introduction or exclusion of the sun's rays, the static method could be adopted without hesitation, and the instrument would become a valuable one for continuous self-recording observations. Their value would be mainly relative. The absolute value of the sun's heat radiation, as it reaches the surface of the earth, has to be determined by other means. When it has been ascertained in the most favourable circumstances it does not vary, excepting in the annual cycle of the earth's revolution. The diurnal variation, as shown by registering actinometers, would have a great local importance. Crova, in the long series of valuable observations which he has made since 1875 at Montpelier, has, in fact, put this principle in practice.

Very important observations have been made in the neighbourhood of Chamonix by Violle and afterwards by Vallot. The Annales de l'Observatoire météorologique du Mont Blanc contain, in vol. ii., several interesting reports on the results of these observations. They were made simultaneously at Chamonix and at certain stations on Mont Blanc. The first series of observations was made in 1887 on July 28, 29 and 30, and the instruments used were two "absolute actinometers" of Violle (*Ann. Chim. Phys.* (1879) [5], t. xvii.).

The great advantage of such experiments is that they are made simultaneously at two stations situated at very different altitudes. At the higher of the two the average barometric pressure is 430 millimetres, so that 33/76 of the whole atmosphere are below the observer, and this portion contains nearly all the aqueous vapour. Above him there is a little more than one-half, and that much the simpler and purer half of the atmosphere. In it aqueous vapour is almost absent. The summit of Mont Blanc is 4807 metres and the station at Chamonix is 1087 metres above the sea. The layer of the atmosphere separating them has, therefore, a thickness of 3720 metres, and it can be visited at any point in its thickness. M. Vallot has acquired a personal acquaintance with this layer of air which can only be obtained by devoting a number of years to living in it and observing it. It is this intimate and continuous acquaintance with so large a proportion of the earth's atmosphere that entitles the observations and conclusions of M. Vallot to especially great weight.

The main results of Vallot's observations are as follows. The ratio between the heat received in the same time by the same area exposed perpendicularly to the sun's rays on Mont Blanc and at Chamonix was found to be 0·82 to 0·85, which agreed well with the proportion found by Violle in 1875. The value of the solar radiation found was, however, much lower than that found by Violle. The maximum values observed by Vallot were 1·56 gr.° C. on Mont Blanc and 1·33 gr.° C. at Chamonix, whilst Violle found 2·39 gr.° C. on Mont Blanc and 2·02 gr.° C. at the Glacier des Bossons in the valley. Violle's observed values are therefore half as great again as Vallot's. No explanation of the cause of this discrepancy is offered, but it is pointed out that the values observed by Crova at Montpelier are more in accordance with Vallot's than with Violle's. They are interesting in themselves and are worth quoting. They relate to the year 1895, the summer of which was very hot.

Intensity of solar radiation observed by M. Crova at Montpelier in 1895, in gramme-degrees per square centimetre per minute:—

| Season. | Means. | | | | Absolute maxima. | |
|---|---|---|---|---|---|---|
| | Monthly. | | | Seasonal. | | |
| Winter ... ... | 1·02 | 1·12 | 1·15 | 1·09 | 1·32 | January 28. |
| Spring ... ... | 1·20 | 1·13 | 1·13 | 1·15 | 1·38 | May 12. |
| Summer ... | 1·22 | 1·14 | 1·19 | 1·18 | 1·42 | July 24. |
| Autumn ... | 1·30 | 1·20 | 1·02 | 1·17 | 1·41 | September 8. |

The subject was taken up again by Vallot in 1891, and this time he used the mercury actinometer of Crova (*Ann. Chim. Phys.* 1877 [5] xi., 461).

The result of the experiments in 1891 was in the main confirmatory of those obtained in 1887. In the following table the intensities of solar radiation on September 19, 1891, are given as observed on Mont Blanc and at Chamonix:—

| Hour. | | 9 a.m. | 10. | 11. | Noon. | 1 p.m. | 2. | 3. |
|---|---|---|---|---|---|---|---|---|
| Observed Radiation. | On Mont Blanc | 1·34 | 1·30 | 1·36 | 1·38 | 1·34 | 1·33 | 1·31 |
| | At Chamonix | 1·11 | 1·16 | 1·19 | 1·15 | 1·16 | 1·09 | 1·01 |
| Ratio of intensities. | | 0·83 | 0·89 | 0·87 | 0·83 | 0·87 | 0·82 | 0·77 |

The mean value of the ratio of the intensities is 0·84, as before. The values of the intensity of radiation are rather lower than those found in 1887.

In the year 1896 Prof. Ångström, of Upsala, made observations on the peak of Tenerife with a special form of actinometer depending on the heating of metal plates. He made observations at three different elevations, namely, at Guimar, 360 metres, Cañada, 2125 metres, and at the summit, 3683 metres. Reduced to a uniform thickness of one atmosphere corresponding to a pressure of 760 mm., the intensity of radiation by the vertical sun was found to be at Guimar 1·39, at Cañada 1·51, and at the summit 1·54 gramme-degrees per square centimetre per minute. These values agree more closely with the values found in 1887 by Vallot than with those of 1891. But the values found by Crova, Vallot and Ångström are all of the same order.

The writer's observations with the steam calorimeter in Egypt in May 1882 were undertaken with the object of ascertaining the maximum rate of distillation near the sea-level under the most favourable circumstances. This occurred during the forenoon of May 18, when the meteorological conditions were as favourable as they could be. The sun shone steadily in a cloudless sky, and the air was motionless. The shade temperature reached 40·5 C. in the course of the day. Time was taken as portions of 5 cubic centimetres were distilled. The shortest time in which this quantity passed was 3m. 20s. This is at the rate of 1·5 c.c. per minute, and it occurred twice in the forenoon, namely, at 10h. 37m. and at 11h. 23m. As the collecting area of the reflector was 904 square centimetres, this corresponds to 16·6 c.c. distilled per minute per square metre. If we apply a correction for 20° zenith distance it becomes 17·04 c.c. The evaporation of 17·04 grammes of water at 100° C. requires 9116 gr.° C. of heat, so that the heat actually collected and used in making steam was at the rate of 9116 gr.° C. per square metre or 0·9116 gr.° C. per square centimetre per minute. Converting 9116 gr.° C. into work at the rate of 0·425 kilogramme-metres per gramme-degree, we obtain as the realised working value 3875 kilogramme-metres per minute or 0·87 horse-power per square metre. The reflector consists of one mirror inclined at an angle of 45° to the axis of the instrument. This mirror throws all the reflected rays normally on the surface of the axial boiler. The larger mirror outside and the smaller mirror inside of this one throw their reflected rays inclined at small angles to the normal. Taking all the reflected rays together their mean normal component is 94 per cent. of the total reflected rays. It is therefore legitimate to increase the above figures in the proportion of 94 : 100, giving 0·93 horse-power or 9700 gr.° C. per square metre per minute. The mirrors are not perfectly reflecting, nor is the blackened surface of the boiler perfectly absorbing. An allowance of 7 per cent. for these deficiencies will not be thought extravagant, and we have in round numbers the work-value of the sun's vertical rays on the surface of the earth at or near the sea-level as 1 horse-power per square metre; the equivalent of this in heat is 10,300 gr.° C. per square metre per minute, or 1·03 gr.° C. taking the square centimetre as unit of area.

Mr. Michie Smith informs the writer that the highest rate which he has observed is 1·754 c.c. distilled per minute at a height of 7000 feet above the sea. This is exactly seven-sixths of the maximum rate observed on the banks of the Nile. If we imagine that in the most favourable circumstances the radiation as determined in Egypt might be improved in this proportion we get 1·17 horse-power per square metre and 1·202 gr.° C. per square centimetre per minute as a value of the heating power of the sun at the sea-level, which is probably very near the truth.

Comparing these results with those already quoted, we see that they agree with Crova's summer values as determined at Montpelier and lie midway between Vallot's (1891) values for Mont Blanc and Chamonix. We arrive therefore at the conclusion that the rate at which the surface of the earth at the level of the sea receives heat in the most favourable circumstances from the vertical sun is 1·2 gr.° C. per square centimetre per minute, or 1·17 horse-power per square metre. In discussing questions of terrestrial physics it would not be prudent to postulate a more abundant supply.

If we ascribe to the atmosphere a coefficient of transmission no greater than two-thirds, the value of the *solar constant*, or the heating power which the sun's rays would exert on a surface of one square centimetre exposed to them for one minute at a point on the earth's orbit, is 1·8 gr.° C. As the transmission coefficient is probably greater than two-thirds, the value of the solar constant is probably less than 1·8. Vallot, by giving effect to the rate of absorption actually observed in the air separating his two stations, arrives at 1·7 gr.° C. as the most probable value. These values are in substantial agreement with the older ones, such as those of Herschel and Pouillet; but there is a feeling at present that not much weight is to be attached to these results, and much higher figures seem to be more readily accepted. In a recent work, "Strahlung und Temperatur der Sonne," p. 38, J. Scheiner sums up the discussion of this subject by giving 4 as the most probable value of the solar constant.

As we have seen, the heat which arrives at the sea-level has to support the temperature of the land and that of the sea; it has also to supply the energy for all the movements of the ocean; it has to warm and expand the air, and to furnish the latent heat represented by the aqueous vapour in the atmosphere, and it is mainly accountable for winds and storms. All this is maintained on less than 1·5 gr.° C. per square centimetre per minute. But when the above catalogue of functions has been repeated, there is nothing left to be accounted for. If the sun's rays enter at the top of the atmosphere with an intensity of 4 and come out at the bottom of it with an intensity of only 1·5, how is the loss to be accounted for? It represents nearly double the energy which reaches the sea-level and produces such far-reaching effects. If it really entered the atmosphere it must be still there, either as heat or as its equivalent. But we know that the air is not made appreciably warmer by it, and we see no mechanical manifestations which can in any way be put forward as an equivalent. We conclude therefore that there is no excess of heat of this order to be accounted for, consequently values of the solar constant of the order of 4 are exaggerated.

J. Y. BUCHANAN.

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## REFLEX ACTION AND INSTINCT.[1]

IN the Paris *Journal of Anatomy and Physiology* of 1869 there was reported by Robin an experiment on the body of a criminal whose head had been removed an hour previously, at the level of the fourth cervical vertebra. The skin around the nipple was scratched with the point of a scalpel. Immediately there ensued a series of rapid movements in the upper extremity which had been extended on the table. The hand was brought across the chest to the pit of the stomach, simultaneously with the semiflexion of the fore-arm and inward rotation of the arm, a movement of defence as it were.

Probably none of us have seen quite so impressive an illustration of reflex action as the above, but most of us have watched the experiment in which a frog, having been decapitated and a drop of acid having been applied to its skin, the foot of the same side is brought up to wipe away the acid, and if this foot be cut off, after some ineffectual efforts and a short period of hesitation, the same action will be performed by the foot on the opposite side. These symptoms of apparently purposive action on the part of a brainless body have always struck me as most strange.

Some four years ago I had the privilege of reading to you a paper on memory, from which I will now quote:—"When we attempt to acquire some new feat of manual dexterity, involving a series of combined muscular movements, such as a conjuring trick, we find that, when first attempted, each movement has to be thought out, and the whole is effected with difficulty. Every time that the process is repeated the action becomes more easy; each movement of the muscles involved follows its predecessor with greater readiness, and at last the trick becomes apparently one action, is performed without thought, and may be said to be automatic. The nerve structures involved have acquired a perfect memory of what is required of them; each takes up its part at the proper moment, and hands on in succession an intimation to its neighbour that it is time to transmit the expected impulse. Nerve centres have been educated. An organic memory has been established."

I went on to give instances in which, by frequent practice, actions had become so habitual as to take place on the application of the stimulus without the will of the individual, and even contrary to his wish. I gave as an illustration the story of the old soldier who was carrying a pie down the street, when some one mischievously crying "Attention!" down went the soldier's hands to his trousers seams, and down went his dinner in the mud.

Let us apply this effect of constant practice to the case in question. The frog has a smooth, soft skin, unprotected by hair or scales. His haunts are stagnant water which swarms with injurious insects and other enemies; or the banks of ponds and streams abounding in sticks and stubs. From the time when the first progressive tadpole protruded his incipient legs, the race of frogs has been brushing away irritating substances. The nerve cells of their spinal cords have established such relations that, whenever a sense of irritation is conveyed to sensory cells, motor cells in connection are brought into action, and a complicated muscular movement follows, without the necessity of the interference of the will.

We may compare the association of nerve cells in the spinal cord to a group of men highly drilled in particular evolutions. Each individual cell of the group maintains relations with others near it by some one or more of its many arms. Upon the receipt of the intimation through sensory nerves and cells that there is something burning a particular portion of the frog's skin, motor

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[1] A paper read before the Derby Medical Society by W. Benthall, M.B., on April 9, 1901